Nutrient Stability in NASA Spaceflight Experiment Rodent Food Bars

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Overview

The Nutrient-upgraded Rodent Food Bars (NuRFB) have a long history as the food of choice for NASA Space Shuttle and ISS Rodent Research missions. The NuRFB have previously been assigned an expiration date of two years after production for use in rodent flight experiments aboard the International Space Station (ISS) and three years for ground experiment use when stored between 2°-10°C. The exiguous supply of cold stowage on the ISS necessitated further investigation to determine if NuRFB can be stored at ambient temperatures (AT) without excessive nutrient degradation. The Rodent Research Project Sustaining Engineering Team at the NASA Ames Research Center in Mountain View, CA is responsible for management of this critical flight product.

CONTACT

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INTRODUCTION

Nutrient-upgraded Rodent Food Bars are the standard diet for mice involved in spaceflight experiments aboard the International Space Station as part of NASA's Rodent Research Project.

These Food Bars are a twin-screw extruded AIN-93G based food product with nutrient additives to preserve a healthy and complete diet for the animals, and the bar form factor is necessary for use in the microgravity environment.

Due to the nature of NASA flight projects and the lengthy production process of these Food Bars, a shelf-life assessment was undertaken to determine nutrient stability over an extended storage time.

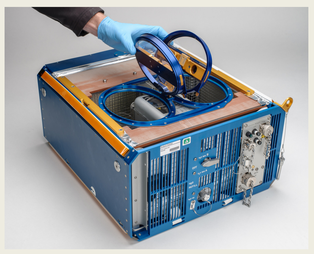
Most sample groups were packaged using a nitrogen flush followed by vacuum seal, while one sample group was packaged without the nitrogen flush, but with an added ethylene oxide sterilization step performed on the Tyvek packaging.

METHODS AND MATERIALS

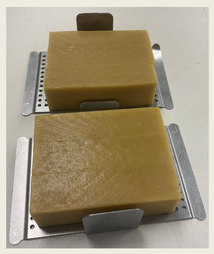
To assess palatability and stability over an extended duration, a panel of lipid oxidation markers and both fat- and water-soluble vitamins were assessed under various time and temperature conditions via AOAC International standardized methodology. Groups were compared to each other using Student's t-tests and one-way ANOVA to test for significance. Data analysis and visualization were performed using pandas, matplotlib, and numPy in Python.

Time point	Time Refrigerated (months)	Time at AT (months)	Rationale/Objective
1	0	6	
1A	0	6	Bag prepared w/EtO. If a failure occurs with the $N_{2(g)}$ preparation this will eliminate single point failure for ambient testing.
2	3	3	Mission scenario replication
3	3	6	
4A+B	6 (Test A here).	6 (Test B here).	To assess if extended storage duration at 4C will result in greater significant loss of nutrients after transfer to AT. To test a mid point of the formula X+2Y=24 as a measure of shelf life. Test A will serve a basal control for Test B.
5A+B	12 (Test A here).	6 (Test B here).	To test the end point of the formula X+2Y=24 as a measure of shelf life. Test A will serve as an internal control for Test B.
6	24	None	Control refrigerated group (4˚C).

Sample Group Definitions



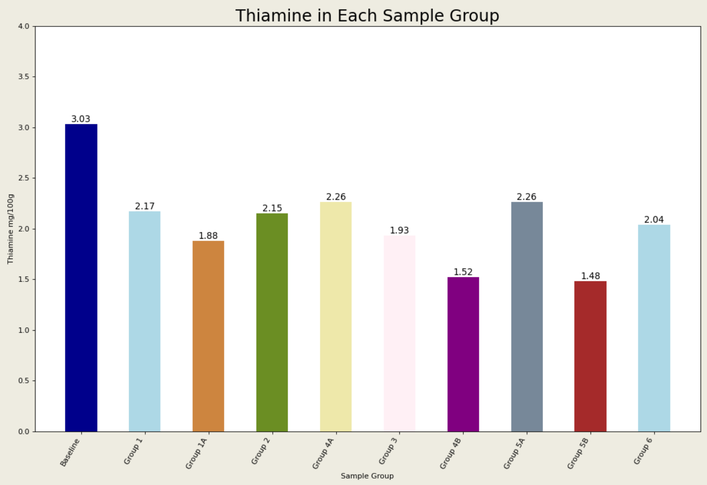
Rodent Research Project Habitat



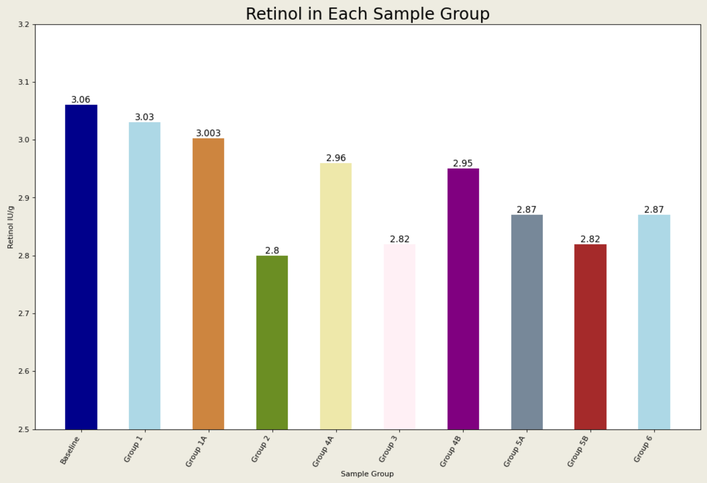
Mounted Food Bars

RESULTS

Food Bars that had been continually kept at 4°C (t=12 months) showed significantly higher levels of thiamine (p = 0.029) compared to Food Bars that underwent some degree of AT storage. No significant difference was seen microbiology testing or riboflavin. Peroxide values in refrigerated versus unrefrigerated Food Bars approached significance (p = 0.056) but ultimately failed to meet the significance threshold. Between groups 2 and 4A there was a significant difference in retinol content (p = 0.028). Both tested at 6 months, group 2 had 3 months of AT and three months of refrigerated storage whereas group 4 remained refrigerated for the entire 6 months. There was a 6.4% decrease in retinol in refrigerated Food Bars after 27 months and an 8.2% decrease at 18 months in bars with mixed temperature storage.



Tested Stability Markers	
Vitamin A as Retinol	Peroxide Value
Vitamin D3	p-Anisidine
Vitamin E	2-Thiobarbituric Acid
Thiamine	Bacteria (aerobic & anaerobic)
Riboflavin	Mold & Yeast
Moisture	TOTOX



DISCUSSION

Thiamine was the least stable vitamin at room temperature. This suggests that refrigeration is a key component in maintaining adequate nutrient levels in these relatively high moisture (average 29.3%) Food Bars. Also of note was the level of Vitamin A in the form of retinol. The data reflect both storage temperature and time as factors affecting the content of this lipid-soluble vitamin. A slow, yet consistent decrease in retinol was observed over the course of the experiment, though at no time did the retinol levels drop below the recommended minimum of 2.4 IU/g.[1]

Some groups however, displayed higher-than-expected aerobic and anaerobic bacteria colony forming units, which is believed to stem from a since-revised handling technique. The use of nitrogen flush has also been discontinued in favor of ethylene oxide sterilization of the packaging.

CONCLUSIONS

Over the 27-month time course, all analyzed nutrients remained relatively stable and at levels which comfortably exceed NRC minimum guidelines and provide fully sufficient nutrition to rodents during extended spaceflight missions. As retinol and thiamine are similarly affected by both time and storage, this will inform future storage requirements for this type of food product. Refrigerated storage is a vital component of the Food Bar lifecycle, but under nominal ambient temperature conditions the Food Bars are not severely affected. These data reflect both the benefits of refrigerated storage and also allow some flexibility in logistical planning when preparing these Food Bars for ground and ISS studies. With animal welfare as a primary concern in these missions, we can attest that the vitamin content is sufficient for the mice and that the lipid profile is quite stable for the duration of the experiments.

REFERENCES

1. National Research Council (US) Subcommittee on Laboratory Animal Nutrition. Nutrient Requirements of Laboratory Animals: Fourth Revised Edition, 1995. Washington (DC): National Academies Press (US); 1995. 3, Nutrient Requirements of the Mouse.

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